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THE BRITISH ASSOCIATION.

SECTION C.

GEOLOGY.

Opening Address[1] by Prof. Grenville A. J. Cole, F.G.S., M.R.I.A., President of the Section.

The geologist has long been accustomed to regard the crust beneath his feet as subject to changes which are immeasurably slow in comparison with the duration of his personal life. James Hutton has sometimes been charged with catastrophic tendencies, in requiring a complete wearing away of the continents, followed by a somewhat sudden restoration of the land-surface. But he was careful to urge[2] that "the powers of nature are not to be employed in order to destroy the very object of those powers; we are not to make nature act in violation to that order which we actually observe." He remarks[3] that "this world is thus destroyed in one part, but it is renewed in another; and the operations by which this world is thus constantly renewed are as evident to the scientific eye as are those in which it is necessarily destroyed." Yet the operations that are to "give birth to future continents," as well as those that wear down a continent to the level of the sea, are not the result of "any violent exertion of power, such as is required in order to produce a great event in little time; in nature, we find no deficiency in respect of time, nor any limitation with regard to power." Far from believing in the complete loss of the former land-surface before upheaval raised the new, Hutton points out that "the just view is this, that when the former land of the globe had been complete, so as to begin to waste and be impaired by the encroachment of the sea, the present land began to appear above the surface of the ocean. In this manner we suppose a due proportion to be always preserved of land and water upon the surface of the globe, for the purpose of a habitable world, such as this which we possess."

Changes in the Relative Proportions of Sea and Land.

Few geologists, however, will now urge with Hutton that a "due proportion" has always been preserved between land and water on the surface of the globe, if by those words is meant a proportion such as we now enjoy. If we go back to early times, we must consider, with R. A. Daly,[4] the possible grouping of the land against which the Huronian or late pre-Cambrian sediments were formed. Daly has imagined, as one of the causes contributing to a "limeless ocean," a primitive distribution of land and water very different from that which determines our continental land to-day. His pre-Huronian land-surface is pictured as merely a number of large islands, on which no long and conspicuous rivers could arise.

It may be said that this primitive condition of the distribution of land and water is very unlikely to return. But we have evidence that Hutton's "due proportion" has been interfered with from time to time. The very general spread of the sea over the land-margins in Cenomanian times is attributable to a shallowing of the ocean-floors, and it is difficult to say whether this process has been rhythmic or exceptional in the history of the globe. The Carboniferous period opened with marine conditions over a large part of the northern hemisphere, indicating, not only a continuation of the Devonian seas, but an overflowing of much of the Caledonian land. The same period closes with an extension of the continental edges, and the formation of swampy flats, in which the vegetation of the epoch has been abundantly preserved. Similarly, the sea which deposited the Cretaceous strata, after encroaching alike on South Africa and Scandinavia, withdrew to a considerable extent in Eocene times.

The Foundations of the Earth's Crust.

Hutton remains at present unassailable in one of his most remarkable propositions. For him, the oldest rocks that we know are sedimentary, and these sediments differed in no respect from those of modern days. This conclusion has perhaps not received the full attention it deserves. It now appears certain that we possess no record of a sedimentary type peculiar to the early stages in the formation of a habitable crust. If such a type existed, it has been lost to us through subsequent metamorphism, amounting to the actual fusion and redistribution of its constituents. The Grenville Series of North America rests on a floor of granitoid rock, which is intrusive in it, and which belongs to the oldest of various irruptive groups. The Grenville Series includes conglomerates, false-bedded quartzites, and a development of limestone that is altogether exceptional for pre-Cambrian times. In Finland,[5] sediments have been traced down to the layer where their original characters vanish in a general "migmatitic" ground. Conglomerates and phyllites occur among them, and near Tampere (Tammerfors) the seasonal stratification is as well recorded in a Bottnian shale as it is in the Pleistocene clays made famous in Sweden by De Geer. Vein-gneiss (Adergneis) underlies these ancient systems, and represents their destruction by the injection of granite from below. If we accept the hypothesis of Chamberlin, Hutton's position becomes strengthened by the postulation of an unfused planetesimal crust, and the restriction of molten masses and hydrothermal activity to the interior of a consolidating globe.

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[1] Abridged by the author.

[2] "Theory of the Earth" (1795), vol. ii., p. 547.

[3] *Ibid.*, p. 562.

[4] "The Limeless Ocean of Pre-Cambrian Time," *Amer. Journ. Sci.*, vol. xxiii. (1907), p. 113; and more fully in "First Calcareous Fossils," *Bull. Geol. Soc. America*, vol. xx. (1909), p. 157.

So far as we have any record left to us, Hutton remains fundamentally in the right. All modern research shows that the schists and gneisses can be explained by causes now in action. The vast majority of schists were at one time normal sediments; others were tuffs or lavas; but, whether originally sedimentary or igneous, they owe their present characters to widely spread regional metamorphism.

The Undermining and Weakening of the Foundations of the Crust.

Is there, then, any reason to depart from Hutton's position as to the recurring cycle of events in the history of continental land? I think it must be admitted that the isostatic balance was far more frequently disturbed in what we may call Lower pre-Cambrian times than it has been in more recent periods. Local fusion must be regarded as an important cause of crustal weakening. If we wish to study the nature of the process, it is reasonable to examine regions that have at one time lain deep within the crust. Such regions are provided by the broad surfaces of Archæan rocks that were worn down through continental decay before they sank beneath the Cambrian sea.

It is well recognised that an ancient continent at one time stretched across the northern hemisphere. Wherever later deposits have been stripped from its surface, from central Canada to the Urals, and probably far beyond, we find that the older materials of this undulating continental platform consist largely of intrusive igneous rocks. These, moreover, have frequently a gneissic structure. Again and again, strongly banded gneisses occur, in which granitic material, verging on aplite, alternates with sheets of hornblendic or biotitic schist. The biotitic varieties can often be traced back into amphibolites. In places, lumps of these amphibolites are seen, streaked out at their margins, and providing a clear explanation of the dark bands throughout the gneiss.[6] This swallowing up of a mantle of basic material by a very different and highly siliceous magma rising from below is, indeed, seen to be a world-wide feature, wherever we find the lower crust-layers brought up within reach of observation. The tuffs and lavas of the Keewatin series have supplied the dark material in Canada, and similar rocks have been worked up into the gneisses of Galway, Stockholm, and Helsinki. The frequency of amphibolite in these ancient composite rocks is explained by the fact that this type of rock is the final term of various metamorphic series. While many lumps, for instance, in the gneisses of Donegal are residues of Dalriadian dolerites (epidiorites), others, rich in garnet and green pyroxene, and often containing quartz, are derived from a mixture of sediments in which limestone has been prevalent.[7] During the absorption and disappearance of these masses in the invading granite magma, the amphibole acquires potassium and breaks down into biotite, and biotite-gneisses result, which may extend over hundreds of square miles.

The details of such an igneous invasion are worthy of careful study, since only in this way can we follow out the progress of subcrustal fusion. We see the highly metamorphosed material further attacked by the great cauldrons under it, and becoming seamed with intersecting veins. Block after block has been caught, as it were, in the act of foundering into the depths. In the gradual absorption of these blocks, and their penetration by insidious streaks of granite, we see pictured on a few square yards of surface the destruction of a continental floor.

The invasion of a "hard and brittle"[8] crust by an attacking magma was finely described by Lawson in 1888. Lawson pointed out that the Laurentian gneisses gave no evidence of having "yielded to pressures and earth-stresses." The folding of the overlying series was prior to the solidification of the gneisses, and occurred[9] "while the latter were yet in the form of probably a thick, viscid magma upon which floated the slowly shrinking and crumpling strata of the Coutchiching and Keewatin series. . . . Large portions of these rocks have very probably been absorbed by fusion with the magma, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Keewatin rock first rested, whatever such floor may have been, but, also, with it, of portions of those series."

The conversion of the lowest Archæan series, the Coutchiching sediments, into crystalline schists is attributed to thermal metamorphism, and to hot vapours streaming from the molten floor. Lawson realised the importance of shattering in allowing a magma to advance into an overlying "brittle" series, and he is, so far as I know, the first observer to develop in satisfying detail what is now known as the stoping theory of igneous intrusion.

James Hutton always had in mind the effect of heat in "softening" lower layers of the crust. His consolidation of strata by heat is preceded by a stage of melting. Sederholm,[10] while referring back to Hutton as the pioneer, shows how in the vein-gneiss stage the unmelted sediments exhibit plasticity and become intensely contorted. The softening, in fact, induces flow. There is here no crushing or mylonitisation, but rather a viscid running of constituents, some on the verge of fusion, some, I venture to think, actually fused. Such rapidly repeated and intricate folding is most intense when *lit par lit* injection has set in, and when the whole composite mass has become weak and plastic. The presence of confined water in aiding this plasticity must on no account be overlooked.

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[5] J. J. Sederholm, "Ueber eine archäische Sedimentformation im südwestlichen-Finland," *Bull Comm. géol. Finlande*, No. 6 (1899), p. 215.

[6] Since the historic works of A. C. Lawson (for example, "Report on Rainy Lake Region," *Geol. Surv. Canada*, Ann. Report for 1887, plates v. and vi.), these features have been traced in many areas. Compare W. H. Collins. "Country between Lake Nipigon and Clay Lake, Ontario," *Geol. Surv. Canada*, Publication 1050 (1909), p. 52; A. L. Hall, Presidential Address on the Bushveld Complex, *Proc Geol. Soc., S. Africa*. 1914, xxii; P. A. Wagner on Rhodesian gneisses, *Trans. ibid.*, vol. xvii., 39; and works cited in the next reference.

[7] See Michel Lévy, "Granite de Flamanville," *Bull. carte géol. France*, vol. v (1893), p. 337; G. A. J. Cole, "Metamorphic Rocks in E. Tyrone and S. Donegal," *Trans R. Irish Acad.*, vol. xxxi. (1900), p. 460; O. Trüstedt, "Die Erzlagerstätten von Pitkäranta," *Bull. Comm. géol. Finlande*, No. 19 (1907), pp. 72 and 92; F. D. Adams and A. E. Barlow, *op. cit.* (1910), pp. 25 and 97; "F. Kretschmer, "Kalksilikatfelse in der Umgebung von Mährisch-Schönberg," *Jahrb. k k. geol. Reichsanstalt*, vol. lviii. (1908), p. 568; etc.

[8] A. C. Lawson, *op. cit.*, p 140. See also his revision of the area, *Geol. Surv. Canada*, Memoir 40 (1913).

[9] *Op. cit.* on Rainy Lake, p. 131.

[10] "Ueber eine archäische Sedimentformation im südwestlichen Finland," *Bull. Comm. géol. Finlande*, No. 6 (1899), p. 133; and "Ueber ptygmatische Faltungen," *Neues Jahrb. für Min.*, Beilage Band 36 (1913), p. 491.

It may be well to illustrate this contention by one or two concrete instances from districts not remote from us at the present time. The noble cliffs of Minaun in Achill Island have been worn by the Atlantic from a mass of evenly-bedded quartzites of Dalriadian age. These are invaded by veins of a very coarse red granite, the main mass of which lies below the present sea-level.[11] The edges of the strata appear fairly horizontal on the cliff-face; but contortion sets in towards the base, and the hard resisting rock has here[12] "undergone intense crumpling and overfolding, such as one meets with on a large scale in mountain ranges, and this contorted flow seems entirely due to the yielding that has taken place in the region of heating." The large size of the constituent crystals of the granite indicates that the surrounding rock was still maintained at a high temperature.

South of Foxford, again, in the county of Mayo, the granite of Slieve Gamph invades a series of mica-schists and quartzites. The margin is cut, as usual, by veins that filled the cracks both of the main granite and the metamorphosed sediments. These sediments have become, prior to the shattering, crumpled and overfolded along the contact-region, and the section upon the glaciated slope resembles that of a fluidal rhyolite on a highly magnified scale.

The wonderful contortion of the composite mass that forms the north end of the Ox Mountains (Slieve Gamph) in the county of Leitrim gives a similar impression of viscid flow. The melting of a single constituent of the invaded schists, which here include amphibolites, would enable them to yield in response to the pressures that were forcing the granite magma in thin sheets between them. Their metamorphism is thermal, and the forces that have produced the crumplings are not those of shearing acting on a solid mass, but may have operated from a distance hydrostatically through the magma.

Again, where limestones occur near granite contacts amid a series of various sedimentary types, they display folded structures in an altogether exceptional degree. Silicates have developed along their bedding-planes, but these have become contorted and rolled upon one another as metamorphism reached its maximum stage. At Maam Cross and Oughterard, in the county of Galway, along the margin of the great granite mass that stretches thence southward to the sea, these flow-structures are conspicuous on weathered surfaces.

The main object of the foregoing discussion is to point out that the Huttonian cycle, in which thermal changes play so large a part, implies a serious weakening of the crust as magmas advance into it from below. The extensive metamorphism of the pre-Cambrian strata, which amounts to a distinctive feature, must, I think, be attributed, not to special intensity of tangential pressures in early times, but to frequency of igneous attack. Much of the crumpling of our schists may result from Hutton's "softening," the pressure being supplied from superincumbent masses, or even hydrostatically, and the flow occurring laterally, or vertically downwards, towards regions where destruction by absorption was going on. The features seen during the falling in of the walls of the lava-lake of Kilauea in Hawaii afford some idea of what takes place in zones of melting within the crust.

Under such conditions in early pre-Cambrian times, even the surface-rocks must have fallen in at some points and have been replaced by igneous extrusions. Isostatic adjustments must have been very frequently disturbed. Folding of rocks, as a phenomenon of lateral surge and flow, must have made itself freely felt at the earth's surface. It is safe to assert that such conditions have not been repeated on a broad scale at any geological period subsequent to the spread of the Olenellus-fauna. Geochemical evolution, however, may have surprises still in store, and, in spite of long tradition, we are disinclined nowadays to rely too strongly on arguments based upon the sanctity of human life.

Possible Breaks in the Slow Continuity of Earth-movement.

1. *The Mountain-building Stage.*

Even with the thickened sedimentary crust beneath us, and the confidence inspired by our limited experience of the earth, we may ask if subterranean changes may not still result in catastrophes at the surface.

What, in fact, is likely to occur if a mountain-building episode again sets in? Such episodes, affecting very wide areas, have undoubtedly recurred in the earth's history. We do not know if they are rhythmic; we do not know if they represent a pulsation, decreasing in intensity, inherited from the stars and hampered by increasing friction; we do not know if they record internal chemical changes, which have no climax, because they are neither cyclic nor involutionary, but evolutionary. The mid-Huronian chains, now worn down and supplying such valuable horizontal sections, were evidently of great extent; but we cannot say that they were vaster than those of later times.

The phenomena accompanying the growth of a single chain in the Cainozoic era give us, at any rate, ample food for thought. Though the narrow cross-section of the core of such a chain limits our field of observation the same inpressings of igneous material, and the same features of rock-weakening and rock-destruction, may be observed as in the immense basal sections exposed in the Archæan platforms. The progress of geological time has not diminished the activity in the depths. The granodiorite of western Montana,[13] for instance, which intruded during an uplift in early Eocene times, has attacked the Algonkian sediments of the district, producing phenomena of stoping and assimilation in the true "Laurentian" style.

In the western and central Alps, again, the absence of any fossiliferous strata older than the Carboniferous arouses some surprise, until we find that many of the granitic intrusions are of late Carboniferous age. The crystalline schists west of Časlav in Bohemia and in the Eisengebirge are now attributed by Hinterlechner and von John[14] to the metamorphism of Ordovician strata by younger granite, which intruded in post-Devonian and probably in Carboniferous times. Much of the gneiss and granite of the Black Forest and the Vosges is now, moreover, removed from the Archæan, and is shown to be associated with the Armorican movements.[15] These vast intrusive masses occupy the place of strata of pre-Permian age. The great development of thermal metamorphism in the Erzgebirge and in Saxony,[16] two classic regions of the dynamometamorphic school, is now widely recognised, and this activity is also assigned to late Carboniferous times. The work of C. Barrois in Brittany is concerned with absorption-phenomena resulting from intrusions during the same mountain-building epoch.

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[11] *Proc. Geol. Assoc.*, vol. xxiv. (1913), Plate 17.

[12] G. A. J. Cole, "Illustrations of Composite Gneisses and Amphibolites in N. W. Ireland," *C. R. Congrès géol. internat.*, Canada (1913), p. 312.

[13] J. Barrell, "Marysville district, Montana: a study of igneous intrusion and contact metamorphism." *U.S. Geol. Survey*, Prof. Paper 57 (1907), and W. H. Emmons and F. C. Calkins, "Phillipsburg Quadrangle," *ibid.*, Paper 78 (1913).

[14] *Verhandl. k. k. Reichsanstalt*, 1910, p. 337, and *Jahrb.*, *ibid.*, vol. lix. (1909), p. 127.

[15] P. Kessler, "Die Entstehung von Schwarzwald und Vogesen," *Jahresberichte Oberrhein, geol. Vereines*, vol. iv. (1914), p. 31.

Sederholm[17] has suggested that the ground above an area affected by processes of mountain-building cracks and becomes faulted, while the more plastic zone below flows under pressure into folds. But the blocks of the "brittle" layer, as Lawson has it, may be seriously displaced by movements in the zone of folding, and subsidences of a regional character may occur. The pressure that has driven an excess of matter to the region of overfolding has squeezed it from beneath an adjacent region. Crumpling and overfolding are accompanied by a shearing away of the matter in one zone from that of another which overlies it; this must result in considerable disturbance of the zone nearer the surface.

We usually regard such disturbances from the uniformitarian point of view. May not, however, actual mountain-building be the break in a slow process of "softening," to use Hutton's term? For a long time the isostatic balance suffers only small disturbances, restoring itself automatically on a gently yielding underworld. Then something gives way; something—a large mass of supporting rock—suffers a change of state. The balance is destroyed abruptly, and mountain-building and rapid subsidences have their day. O. Ampferer,[18] with his customary largeness of view, has referred superficial evidences of disturbance, such as mountain-ranges, to dragging movements of a mobile *Untergrund.* He urges that physical and chemical changes within the earth may produce considerable local changes of volume. Vertical movements lead to upfolding, and this leads to gravitational sliding. The zone of folding that we have been considering as normal near the *Untergrund* thus becomes transferred to the surface of the earth.

I am not now concerned with the causes of folding, beyond the fact that at a certain critical stage the material involved may move at a rapid rate. Changes of state, physical and chemical, occur with some abruptness. In the case of rocks, the softening or melting of even one constituent may allow of flow, and, as we have observed, this flow in a lower layer may soon become manifested in surface-changes.

Ampferer and Hammer[19] have recently considered the overfolded structure of mountains as due to a considerable local reduction in volume of the *Untergrund.* The upper crust presses inwards from opposite sides, and the parts that are thrust downwards become absorbed and carried away with the retreating region of the *Untergrund.* The surviving parts fall over on either side, producing, as the whole continues to close in, folds that are not so very different from the now familiar *nappes de recouvrement* which these authors hesitate to accept. The important point for our present purpose is the restatement of the results of gravitation on the flanks of an uprising chain.

The surprising thing about our folded mountain-chains is the way in which they have been eroded parallel to the strike of the overthrust sheets or overfolds. Apart from occasional detached "klips," the distal parts of these masses must have been at one time continuous with those proximal to the root-region. The forward movement could not have occurred if denudation had negatived the effects of folding on the surface.

The marine or lacustrine deposits of the age immediately preceding that of uplift obviously cannot be consolidated at the epoch of upheaval. Gotlandian sands and muds must have overlain the heaving masses that rose as Caledonian land. The swamps of the Coal Measures were contorted in the Armorican chains: the highest beds of these must have been as yielding and as capable of flow as the Flysch that overlay the growing Alps. In all these cases, familiar to us in Europe, the covering masses must have responded to the crumpling under them, and, when reared to dangerous eminences, rapidly became a prey to denudation and gravitational downsliding. They can scarcely be regarded as protective, and their removal would leave the brittle masses below more liable to fracture and to the "calving" process that forms klips.

In some cases separation seems to have taken place as the moving mass fell forward. The klips of hard material embedded in softer strata are thus a kind of rock-spray, hurled in advance of the breaking earth-wave.

Termier[20] in no wise fears to speak of the progress of a "traîneur écraseur" during mountain-building as "soudain et rapide comme une rupture d'equilibre, le dernier acte, longuement péparé, mais joué d'*emportement,* de ce drame grandiose."

Rupture combined with rapid movement of the rocks need not be the last act of the drama; but, the more we examine the history of folded chains, the more probable it appears as a culminating episode. The original cover of our present ranges has been lost by denudation. Earth-sculpture in these regions of high altitude and vehement attack has removed much of the evidence that we seek. What remains, however, may lead us to feel that no part of the world in historic times has experienced a mountain-building episode.

Such relatively catastrophic stages have, indeed, not been common in the long history of the earth since pre-Cambrian times. It appears that now and again the "orogenic collapse" of some considerable area disturbs the balance in the crust and spreads far through the upper layers like a disease. Or it may be that the thermal cause of the collapse is common to the whole earth at the same time, and becomes manifest in responsive regions far apart. In any case, the weak places give way and the more resisting ones close in. A readjustment is effected, which then endures through long geological time.

The imminent menace of crustal changes was brought home to us during the terrible period from April 4, 1905, to January 14, 1907, the final twelve months being marked by a veritable earth-storm. Geologically speaking, however, we are near enough to the Tortonian epoch to look forward with some confidence to a quiescent phase. But some day, in its due season, the earth will once more be active. When that time comes, no ingenuity of man will suffice to meet it. Earthquake after earthquake, increasing in intensity, will probably have driven the population to a distance from the threatened zone. Concentration of the folding along a particular earth-line will limit the region of absolute destruction; but the undulations spreading from it, in response to the heavings of the chain, will offer sufficient chances of catastrophe. In the case of our youngest mountain-ranges, these undulations remain perpetuated as domes and dimplings of the crust, which are already worn down or infilled respectively by denudation and deposition. Their present forms and places record the last movements of the earth-storm, just as a buckled tramway-rail records the passage of an earthquake. How shall we gauge to-day the intensity of their rise and fall?

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[16] C. Gäbert, *Zeitschr. deutsch. geol. Gessell.*, vol. lix. (1907), p. 308; R. Lepsius, "Geologie von Deutschland" (1910), pt. 2, pp. 107 and 172.

[17] *Op. cit.*, *Bull. Comm. geol. Finlande*, No. 37, p. 66.

[18] "Das Bewegungsbild der Faltengebirgen," *Jahrb. k. k. geol. Reichsanstalt*, vol. lvi. (1906), p. 607.

[19] O. Ampferer and W. Hammer, "Geologischer Querschnitt durch die Ostalpen," *Jahrb. k. k. Reichstanstalt*, vol. lxi. (1911), p. 700.

[20] "Les Problèmes de la Géologie tectonique dans le Méditerranée occidentale," *Revue générale des Sciences*, March 30, 1911.

In the case of the city devastated by an earthquake, the débris is cleared away, and our descendants in time discover the distorted rails beneath the healing mantle of new grass. Will they realise from this alone the preliminary tremors, the sudden arrival of the culminating vibration, the shock that overcame the elasticity of the crust beneath them, and then the gradual establishment of the conditions under which they have passed their peaceful lives? The crumpled wreckage lies there in evidence before them; but how will they distinguish the work of a few stormy seconds from that due to the gentle earth-creep of a century?

(2) *Regions of Subsidence.*

It was probably E. Suess who brought home to most of us the importance of regions of subsidence in defining the lowlands and the sea-basins from the upstanding masses of the crust. While one region may be folded, another may be broken into blocks; and the two types of movement, that due to tangential thrusting and that due to vertical uplift and down-faulting, may appear in the same region and may alike play their part in producing a lowering of large areas. The domes and dimples that occur beyond the region of acute crumpling may be intensified into fault-blocks by fracture of their boundaries. If catastrophes are possible during uplift, we may look for them also during subsidence.

The cutting-up of mountain-chains by transverse fractures has resulted in the loss of huge blocks beneath the sea. In such cases it is clear that faulting has run a long way ahead of denudation. All trough-valleys, which are often called, somewhat misleadingly, rift-valleys, raise the same questions as to the nature of the steps by which they have been produced. The Rhine Vale, one of the most closely studied examples, dropped 8000 ft. within the limits of Oligocene time. It is improbable that the numerous faults now traceable operated with concerted gentleness.

Abruptness of certain Geographical Changes.—River-capture.

There is a totally different class of terrestrial phenomena which lends itself also to speculation, or to that imaginative faculty, proper to our Section, which enables the geologist to reconstruct. Geographers have taught us to speak lightly of river-diversion and river-capture, and to treat them as frequent occurrences in the history of existing lands. It is interesting to inquire what this process on a large scale may involve.

The draining of the Ragunda lake in Sweden[21] in 1796, by the rapid cutting of a ravine 100 ft. deep in a soft barrier, shows how many of our Glacial lakes, dammed by morainic matter, may have excavated their outlet gorges and run dry in the course of a few hours. The history of the temporary lake behind the Gohna landslip, so brilliantly studied by our vice-president, Sir Thomas Holland,[22] provided a lesson both in hill-destruction and catastrophic flooding. The diversion of the Colorado River, however, in 1905, into the sluice leading to the Salton Sink gives us a definite illustration of river-capture. The "New River" thus produced in the depression to the north-west of Calexico cut a valley 70 ft. deep through the agricultural land that it was meant to serve, and worked the head of this valley backward at the rate of a third of a mile a day.

One of the most remarkable instances of river-diversion in the European record is that of the waters from the north side of the central Alps. At the close of the Pliocene period, the north slopes of the St. Gothard mass and the Bernese Alps, supplying the torrents of the Reuss-Aar-Saane system, drained across the hummocky land near Bâle and sent their waters over to the Doubs. The great Rhine-trough drained southward, and its streams formed tributaries of the Alpine flow near Bâle. The Mainz basin, however, which was infilled by Lower Pliocene alluvium, became tapped by the head of a river that had long run northward from the Hunsrück-Taunus range. This river is the Rhine that we know north of Coblenz, and its alluvium was then spread out where the sea now stretches between Holland and the Yorkshire coast. Its mature valley is still traceable[23] above the present stream-cut in the hills. This river could have no direct influence on the course of the drainage from the Alps. But the bulging of the land at the north end of the Juras still continued. As the text-books remark with some complacency, the Burgundian gate was closed, and the river that had previously crossed westward was diverted northward to the Rhine-trough.

Can we exactly picture what this means? The whole Reuss-Aar-Saane system "on some particular day began to flow northward along the far older tectonic trough, carving away the infilling of detritus, washing back tree-stems that were floating quietly from the Lake of Mainz on their way to the Mediterranean, and finding, when it reached that lake, a notch sufficiently low for its escape across the Hunsrück-Taunus range. An enormous body of water was thus added to that which had formed in Pliocene times a mature valley across these hills."[24] The system indicated above, representing the flow from a hundred miles of snow-clad mountains, must have made a remarkable change in the stream across the Armorican hills. When the Alpine water arrived at the Mainz basin, and found its way into the notch formed by the Pliocene Rhine, it poured down upon the forest-covered delta-land. The changes that have occurred in the unconsolidated ground of Holland in historic times furnish some picture of what must have happened in the prehistoric delta of the Rhine. Land was suddenly built up at some points, islands were carved out at others, and the effects of the catastrophe must have been still manifest when the Scandinavian ice-sheet began to invade the mud-flats from the north.

The capture of a large river may be illustrated by the story of the Vistula. This noble stream represents in a remarkable way the drainage of 190 miles of the Carpathians. All this water becomes concentrated, at the apex of a reversed river-fan, at the east end of the Kielce hills, and it is probable that the upper Vistula was driven to join the San by the advancing ice-front of the Riss age, and that both rivers then escaped southwards. The joint waters were again held up when the Fennoscandian ice rested along the line marked by the Baltic Heights, and it is well known that a great river flowed westward along the stagnating ice-front where now the marshes of the Netze mark its course. As the ice-front shrank backward, towards the Baltic basin,[25] streams flowed down over the sands and boulder-clays and cut their valley-heads back southward. Overflows may have taken place on the unconsolidated wall of the great east-and-west river, which was now deprived of its barrier of moraine-filled ice. In one way or another, the shallow valley of the main river was tapped near Kustrin, and the Oder, rising in the Moravian plateau, was sent northward as an independent stream. Similarly, the Vistula was carried off at Fordon, where the bend due to capture is conspicuous at the present day; and the whole drainage of the north wall of the Carpathians swept across the drift deposits down the course of some hitherto unimportant stream. Along the valley thus carved out, brown and yellow cliffs now rise above the marshy flood-plain, and the red castles of advancing Germany have for centuries looked down firmly on the stream. It is quite contrary to our customary philosophy, but a good corrective all the same, to ask ourselves if this lower valley of the Vistula, eighty miles in length, was shaped in a few months or a few years. The main part of the excavation, across unconsolidated lands, may have occupied less time than the building of the strongholds at the fords.

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[21] See especially H. W. Ahlmann, "Ragundasjöns Geomorfologoi," *Sveriges Geol. Undersök*, 1915; also Ahlmann, Carlzon, and Sandegren, "Quaternary History of the Ragunda Region, Jämtland," *Geol. Fören. Förhandl.*, vol. xxxiv. (1912), p. 343.

[22] Records Geol. Surv. India, voi. xxvii. (1894), p. 55, and NATURE, vol. l., p. 501.

[23] W. M. Davis, "Die erklärende Beschreibung der Landformen" (1912), p. 106.

[24] G. A. J. Cole, "The Growth of Europe" (1914) p. 109.

[25] R. Lepsius (*Geologie von Deutschland*, pt. 2, p. 511) urges that the sinking of the floor of northern Europe led to this northward trend of the streams.

Conclusion.

In spite of the swamping of the Alkmaar country in 1825, in spite of the tragedy of Messina only seven short years ago, we feel that Europe is a settled continent, and we judge the past and future by the present superficial peace. We have applied the same thoughts to human movements, and the inconceivable has happened in our midst. We naturally find it difficult to carry our minds back to epochs when the earth-blocks may have parted asunder as ice parts across the polar seas. We have still, however, very much to learn about causes now in action; and the mystery of the earth, and of our connection with it, grows upon us as we learn. Can we at all realise the greatest change that ever came upon the globe, the moment when living matter appeared upon its surface, perhaps over a few square miles? Matter is either dead or living, that is, endowed with life; there is no intermediate state. And here was living matter, a product of the slime, if you will, but of a slime more glorious than the stars. Was this thing, life, a surface-concentration, a specialisation, of something that had previously permeated all matter, but had remained powerless because it was infinitely diffuse? Here you will perceive that the mere geologist is very much beyond his depth. Let us return to our orderly studies, our patient hammerings, our rock-slices, our chiselling out of fossil shells. Behind it all is the earth itself, quiescent, it may be, but by no means in the sleep of death. As Termier puts it, "La planète n'est pas encore morte; elle ne fait que dormir." If in this address I have dwelt upon the possibility of rapid changes in its surface, no member of our association will feel the least alarm.

> Felix qui potuit rerum cognoscere causas,
> Atque metus omnes, et inexorabile fatum
> Subiecit pedibus, strepitumque Acherontis auari.

SECTION E.

GEOGRAPHY.

OPENING ADDRESS[1] BY MAJOR H. G. LYONS, D.Sc., F.R.S., PRESIDENT OF THE SECTION.

The Importance of Geographical Research.

THIS year, when the British Association is holding its meeting in times of the utmost gravity, the changed conditions which have been brought about by this war must occupy the attention of all the sections to a greater or less extent, and our attention is being called to many fields in which our activities have been less marked or more restricted than they might have been, and where more serious study is to be desired. The same introspection may be usefully exercised in geography, for although that branch of knowledge has undoubtedly advanced in a remarkable degree during the last few decades, we have certainly allowed some parts of the subject to receive inadequate attention as compared with others, and the necessity for more serious study of many of its problems is abundantly evident.

In order that we may see what advance has been made in the scientific study of geography in this country during the last quarter of a century, we must turn to the results that have been attained by the activity of geographical investigators who have devoted themselves to the serious study of various phenomena, and the detailed investigation of particular regions. If we do so I think we must admit that the number of original investigators in scientific geography who are extending its scope in this way is not so large as it might be, nor are we yet utilising sufficiently all the material which is available to us. Anyone who will examine the geographical material which has been published in any period which he may select for review will find that purely descriptive treatment still far outweighs the analytical treatment which alone can lead to definite advances in scientific geography. If pleasing descriptions of this or that locality are sought for, they are for the most part to be found readily in the very large amount of such material that has been and is being published each year by residents, travellers, and explorers; but if information is desired in the prosecution of a piece of geographical research, we are checked by the lack of precise details Few descriptions of this class are sufficiently definite to enable the necessary comparisons to be made between one locality and others which are similarly situated; thoroughly quantitative treatment is for the most part lacking, and while a pleasing picture is drawn which is probably true in character, it is usually inadequately furnished with those definite facts which the geographer requires.

The opportunity to undertake long journeys through distant lands comes to few of us, but this is not the only direction in which research can be profitably undertaken, for there is no part of these islands where a geographer cannot find within his reach some geographical problem which is well worth working out, and which, if well and thoroughly done, will be a valuable contribution to his science. Even for such as cannot undertake such field work the library will provide a host of subjects which have not received nearly the amount of attention and of careful study that they deserve. The one thing essential is that the study should be as thorough as possible, so that all the contributory lines of evidence shall be brought together and compared, and so that the result may prove to be a real addition to geographical science on which other workers may in their turn build.

The ease with which a tract of country or a route can be described by the traveller, and the attractiveness of such a description of a little-known region, results in the provision of a vast quantity of geographical information, the greater part of which has probably been collected by those who have no adequate training in the subject. But anyone who has had occasion to make use of such material in a serious investigation is only too well aware how little precise and definite information he will be able to extract from the greater part of this wealth of material, and in most cases this is due to the traveller's lack of geographical knowledge. He probably does not know the phenomena which should be observed in the type of region which he is traversing, nor can he read the geographical evidence which lies patent to a trained observer at every point of the journey; much, therefore, of what he records may be of interest, but probably lacks data which are essential to the geographer if he is to understand the geographical character of the region, and utilise it properly.

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[1] Slightly abridged by the author.

Thus it happens that although the amount of geographical material which is being garnered may be large, the proportion of it which is available for use in a scientific investigation of an area is smaller than is probably realised by those who have not made the experiment. And yet it is only by this scientific investigation of selected localities or of a single phenomenon and by working them out as thoroughly as possible that any real advance in geographical science can be made. There should now be an ever-increasing number of geographers trained to proceed in their investigations by the true scientific method, and there should be a very considerable amount of sound work in various branches of the subject which aims at thoroughly investigating some phenomenon, or group of phenomena, so as to present a grouping of data, carefully verified and critically discussed, in order to arrive at conclusions which may form a useful addition, however small, to the sum of our geographical knowledge.

So far as I am able to judge, the output of serious work of this character is not nearly as large as it should be, and I would indicate some fields in which there is a lack of individual work of this character. Until more of it is undertaken we shall lack in this country the material from which the foundations of scientific geography can be built up, and while our own islands and the various parts of the British Empire furnish unrivalled opportunities for such work, there are still far too many subjects where the most thorough investigations have been made in other countries.

Mathematical geography presents a field for research which has had comparatively little attention paid to it in this country. In many respects this part of the subject is peculiarly suitable for such treatment, since it admits of the employment of precise methods to an extent which is not always practicable in cases where so many of the factors can only be approximately defined. The determination of positions on the earth's surface is carried to great refinement in the national surveys of most civilised countries in order to furnish the necessary controls for the preparation of large-scale maps, but when we pass to the location of travellers' routes, where considerable allowance has to be made for the conditions under which the observations have to be taken, we find that very inadequate attention is usually paid to the discussion of the results. Usually a mean value for each latitude, longitude, or azimuth is obtained by the computer, and he remains satisfied with this, so that when the route of another traveller follows the same line or crosses it at one or more points, it is almost impossible for the cartographer to say which of the two determinations of any position is entitled to the greater confidence. In this class of work, whether the results are obtained from absolute observations at certain points or from the direction of march, and the distance traversed, it is quite practicable to determine the range of uncertainty within which the positions of different points are laid down, and it is eminently desirable that this should always be done in order that the results of various routes which may intersect in partially known regions may be adjusted in accordance with definite mathematical processes. Some important expeditions on which infinite labour and considerable sums have been expended have presented their results, in so far as they relate to the routes which have been followed and the position of points which have been determined, in such a way that it is impossible to say with what precision such positions have been determined, and consequently any combination of these results with those of later expeditions has to be carried out empirically, since adequate data are no longer available for the employment of better and more scientific methods.

This crude and unsatisfactory way of treating observations, which in many cases have been obtained under conditions of the greatest difficulty and even hardship, is largely due to the lack of interest which geographers have shown in this part of their subject. Methods of observation and methods of computation are rarely discussed before any of our geographical societies or in any of our publications, and it is only by such discussions that the importance of properly working out the available material at a time when the observer can be consulted on points which are doubtful, or where further explanation is desirable, becomes generally appreciated.

No set of physical or astronomical observations is ever discussed or even presented without the degree of precision or trustworthiness being definitely stated; yet in geography this sound rule is too often neglected.

There are several regions where travellers' routes intersect which should provide ample material for the careful reduction and adjustment of the results. I fear, however, that there would be great difficulty in obtaining the original observations which are indispensable in such an investigation, and in the interest of research it is highly desirable that the original documents of all work of importance should be preserved and the place where they may be consulted should be recorded in the published account.

There is room in the geographical investigation of sea and land, even within the limits of the British Empire, for the employment of methods of observation and computation of the highest precision as well as of the simpler and more approximate kinds, but everyone who presents the results of his work should deem it his first duty to state explicitly the methods which he employed, and the accuracy to which he attained, in such a form that all who make use of them can judge for themselves of the degree of their trustworthiness.

In such work, while the instruments used are of great importance, too often the briefest description, such as "a 4-in. theodolite," is deemed sufficient. If the observer wishes his work to be treated seriously as a definite contribution to science we require to know more than this, and a clear account of the essentials of the instrument, a statement of its errors, and of the methods of observation adopted are the least that will suffice. The account of any expedition should treat so fully of the instruments, observations, and computations utilised to determine the positions of places visited that anyone can re-examine the evidence and form his opinion on the value of the results obtained. A mere tabular statement of accepted values, which frequently is all that is provided, is of small value from a scientific point of view. Probably one reason for this state of things is that too little attention is being paid by geographers to their instruments. Theodolites, levels, compasses, clinometers, tacheometers, plane-tables, pantographs, co-ordinatographs, planimeters, and the many other instruments which are used by the surveyor, the cartographer, the computer, have in no case arrived at a final state of perfection, but it is seldom that we find a critical description of an instrument in our journals.

Descriptions there are from time to time, but these are for the most part weak and insufficient. Not only is a technical description required, which treats fully of both the optical and mechanical details, but we need an extended series of observations with the instrument which have been made under the ordinary conditions of practical work, and these must be mathematically analysed, and the degree of the trustworthiness of the results clearly demonstrated. The description should be equally thorough and complete, including scale drawings showing the construction of the instrument as well as photographs of it. Nothing less than this is of any use to the scientific cartographer.

In this country the early advances of British instrument-makers of surveying instruments are far from being adequately represented in our national museum in a manner commensurate with their importance. The keen and enlightened zeal of geographers who are interested in this branch of the subject would doubtless quickly bring to light much still remaining that is of great interest, but which is yet unrecognised, while a closer attention to instrumental equipment would lead to improvements and advances in the types that are now employed. There is no modern work in this country on the development of such instruments, and references to their history are conspicuously rare in our journals, so that there is here an opportunity for those whose duties prevent them from undertaking travel or exploration of a more ambitious kind. In the same way, those whose opportunities of field work are few can find a promising field of study in the early methods and practice of surveying which have been discussed by many authors from classical times onwards, and for which a considerable amount of material exists.

In geodesy and surveying of high precision there is ample scope for all who are attracted by the mathematical aspect of the subject; the critical discussion of the instruments and methods employed and results obtained, both in this country and in other lands, provides opportunity for much work of real value, while its bearing upon geology, seismology, etc., has not yet been adequately treated here. The detailed history of this part of our subject is to be found in papers which have been published in the technical and scientific journals of other countries for the most part; here too little attention has been given to the subject, in spite of the large amount of geodetic work which has been executed in the British Empire, and which remains to be done in our Colonies and overseas Dominions.

The final expression of the surveyor's detailed measurements is found in the map, and the adequate representation of any land surface on a map-sheet is both a science and an art. Here we require additional work on all sides, for there is scarcely any branch of geography which offers so remunerative a field for activity as cartography. We need the cooperation of trained geographers to study requirements, and to make acquaintance with the limits of technical methods of reproduction, so that they may be in a position to deal with many questions which arise in the preparation of a map regarding the most suitable mode of presentation of data, a matter which is purely geographical, but which at the present time is too often left to the skilled draughtsman. Neither the compilation nor the reduction of maps is a merely mechanical process. The first requires great skill and care as well as technical knowledge and a sound method of treatment if the various pieces of work, which are brought together to make up the map of any considerable area, are to be utilised according to their true worth. This demands a competent knowledge of the work which has been previously done on the region, a first-hand acquaintance with the data collected by the earlier workers, and the critical examination of them in order that due weight may be given to the better material in the final result. This is not a task to be handed over to the draughtsman, who will mechanically incorporate the material as though it were all of equal accuracy, or will adjust discrepancies arbitrarily and not on any definite plan. Such preliminary preparation of cartographical material is a scientific operation which should be carried out by scientific methods and should be completed before the work reaches the draughtsman, who will then have but to introduce detail into a network of controls which has been prepared for him and of which the accuracy at all points has been definitely ascertained. Similarly in the second case the elimination of detail which must of necessity be omitted is an operation needing the greatest skill, a full understanding of the material available, and an adequate appreciation of the result which is being aimed at, such as is only to be found in a competent geographer who has made himself intimately acquainted with all the material which is available and has his critical faculty fully developed.

All these problems are well within the reach of the geographer to whom the opportunity of travel in other regions does not come, and in them he will find ready to his hand a field of research which is well worth working and which will amply repay any labour that is spent upon it. The same precise methods of investigation which are employed in the discussion of observations should be applied to all cartographic material in order to ascertain the exact standard of its trustworthiness, in which is included not only the correctness of distance and direction, but also the accuracy of the information which has been incorporated in it; and these may be brought to bear also on those early maps of which so many are preserved in our libraries in this country. In this field of study several investigators have already achieved results of great interest and value, but I think they will be ready to admit that there is here a wide and profitable field of activity for many more workers who will study closely these early maps and, not being contented with verbal descriptions, will use quantitative methods wherever these are possible.

In the study of map projections some activity has been visible in recent years, and we may hope that those who have worked in this branch of the subject will see that British geography is provided with a comprehensive manual of this subject which will be worthy of the vast importance of cartography to the Empire. The selection of suitable projections is receiving much more attention than was formerly accorded to it, but the numbers of communications on this subject which reach geographical journals are few and far between. The subject is not one which can appeal strongly to the amateur geographer, but its importance renders it imperative that the scientific geographer who realises its intimate bearing upon all his work should so arrange that the matter does not fall into the background on this account.

But it may be suggested that the lack of activity in mathematical geography is due to the somewhat specialised nature of the subject, and to the fact that the number of those who have received an adequate mathematical training and are prepared to devote themselves to geography is few. When we turn to physical geography in its treatment of the land we do find a field which has been more actively worked, for this is just the one to which the traveller's and explorer's observations should contribute most largely, and where therefore their material should be utilised with the best results. Even here there is room for much more work of the detailed and critical type, which is not merely general and descriptive, but starts from the careful collection of data, proceeds to the critical discussion of them, and continues by a comparison of the results with those obtained in similar observations in other regions.

To take a single branch of physical geography, the study of rivers, the amount of accurate material which has been adequately discussed is small. In our own country the rainfall of various river basins is well known through the efforts of a meteorological association, but the proportion of it which is removed by evaporation, and of that which passes into the soil, has only been very partially studied. Passing to the run-off, which is more easy to determine satisfactorily, the carefully measured discharges of streams and rivers are not nearly so numerous as they should be if the hydrography of the rivers is to be adequately discussed; for although the more important rivers have been gauged by the authorities responsible for them in many cases, the results have usually been filed, and the information which has been published is usually a final value, but without either the original data from which it has been deduced, or a full account given of the methods of measurement which have been employed. For the requirements of the authority concerned such a record is no doubt adequate, but the geographer requires the more detailed information if he is to co-ordinate satisfactorily the volume discharged with local rainfall, with changes in the rates of erosion or deposition, and the many other phenomena which make up the life-history of a river. Here, too, it is usually only the main stream which has been investigated; the tributaries still await a similar and even fuller study.

In the same way we still know too little of the amounts of the dissolved and suspended matter which is carried down by our streams at various seasons of the year and in the different parts of their course.

In this one branch of the subject there is ample scope for workers of all interests in the measurement of discharges, in the determination of level, and of the movement of flood waves, in determining the amount of matter transported both in suspension and in solution, in tracing out the changes of the river channel, in following out the variation of the water-table which feeds the stream, in ascertaining the loss of water by seepage in various parts of its course, and generally in studying the hundred other phenomena which are well worth investigating, and which give ample scope for workers of all kinds and of all opportunities. There is work not only in the field, but also in the laboratory and in the library which needs doing, for the full account of even a single stream can only be prepared when data of all classes have been collected and discussed.

On the Scottish lakes much valuable scientific work has been done, and also on some of the English lakes, so that excellent examples of how such work should be done are available as a guide to anyone who will devote his spare time for a year or two in making a thorough acquaintance with the characteristics and phenomena of any lake to which he has access.

Coast-lines provide another class of geographical control which repays detailed study, and presents numberless opportunities for systematic investigation and material for many profitable studies in geography. The shores of these islands include almost every variety of type, and furnish exceptional opportunities for research of a profitable character, especially as lying on the border-line between the domain of the oceanographer on one hand and the physiographer on the other. The precise methods of representation which are possible on the land have to give way to a more generalised treatment over the sea, and the shore line is liable to be handed over to the latter sphere, so that there is much interesting and useful work open to anyone who will make an accurate and detailed study of a selected piece of coast-line, co-ordinating it with the phenomena of the land and sea respectively.

The teaching of Prof. Davis in pressing for the employment of systematic methods in describing the landscapes with which the geographer has to deal has brought about a more rational treatment, in which due recognition is given to the structure of the area, and the processes which have moulded it, so that land forms are now for the most part described more or less adequately in terms which are familiar to all geographers and which convey definite associated ideas, in the light of which the particular description is adequately appreciated. It has been urged by some that such technical terms are unnecessary and serve to render the writings in which they occur intelligible only to the few; that anyone should be able to express his meaning in words and sentences which will convey his meaning to all. There is no great difficulty in doing this, but in such descriptions to convey all that a technically-worded account can give to those who understand its terms would be long and involved on account of the numerous related facts which would be included. It is consequently essential in all accurate work that certain terms should have very definite and restricted meanings, and such technical terms, when suitably chosen, are not only convenient in that they avoid circumlocution, but when used in the accepted sense at once suggest to the mind a whole series of related and dependent conditions which are always associated with it.

The crystallisation of such geographical terms into true technical terms is an important step in the furtherance of scientific geography, but it must be done by the geographers themselves, and no means of doing this is more fruitful than the work of original research and investigation in definite areas or on specific problems.

If we now consider some of the problems of human geography we shall find the need for such systematic study to be even greater; for the variable factors involved are more numerous than in physical geography, and many of them are difficult to reduce to precise statement; the quantitative study of the subject is therefore much more difficult than the qualitative or descriptive, so that the latter is too frequently adopted to the exclusion of the former. The remedy lies, I believe, in individual research into special cases and special areas where the factors involved are not too numerous, where some of them at least can be defined with some accuracy, and where, consequently, deductions can be drawn with some precision and with an accuracy which gives grounds for confidence in the result. The settlements of man, his occupations, his movements in their geographical relations are manifested everywhere, and subjects of study are to be found without difficulty, but their investigation must be based on actual observation, and on data which have been carefully collected and critically examined, so that the subject may be treated as completely as possible, and in such a way that the evidence is laid before the reader in order that he may form his own conclusions.

It is probable that some of the lack of precision which is to be found in this part of the subject is to be attributed to the want of precision in its terminology. For many things in human geography good technical terms are required, but these must be selected by those who have studied the type of phenomenon concerned and have a clear idea of the particular conditions which they desire to associate with the term;

this is not the work of a committee of selection, but must grow out of the needs of the individual workers.

There is, it must be admitted, no small difficulty in using the same preciseness of method in this portion of the subject as is readily attainable in mathematical geography, and is usually practicable in physiography; but at any rate it is undesirable to indicate any condition as the controlling one until all other possible influences have been carefully examined, and have been shown to have less weight than that one which has been selected.

Whether the investigation deals with the settlements of man or his movements and means of communication, it is important that in the first instance problems of a manageable size should be undertaken and thoroughly treated, leaving larger areas and wider generalisations until a sufficient stock of thoroughly trustworthy material which is in the form in which it can properly be used for wider aims is available.

The relation of geographical conditions to small settlements can be satisfactorily worked out if sufficient trouble is taken and all possible sources of information, both of present date and of periods which have passed away, are utilised. Such studies are of a real value and pave the way to more elaborate studies, but we need more serious study of these simpler cases both to set our facts in order and to provide a methodical classification of the conditions which prevail in this part of the subject. Out of such studies there will grow such a series of terms with well-defined associations as will give a real precision to the subject which it seems at the present time to lack.

The same benefit is to be anticipated from detailed work in relation to man's communications and the interchange of commodities in all their varied relations. Generalised and descriptive accounts are readily to be found, and these are for the most part supported by tables of statistics, all of which have their value and present truths of great importance in geography, but the spirit of active research which aims at clearing up thoroughly a small portion of the wide field of geographical activities has unequalled opportunities in the somewhat shadowy relations between the phenomena which we meet in this part of the subject, for focusing the facts better, and obtaining a more exact view of the questions involved.

Where the geography of States (political geography) is concerned the same need for original investigation as a basis for generalisations may be seen. At the present time there is much said about the various boundaries of States, and in general terms the advantages and disadvantages of different boundaries under varied conditions can be stated with fair approximation to accuracy. But I do not know of many detailed examinations of these boundaries or portions of them where full information of all the factors involved can be found set out in an orderly and authoritative manner, thus forming a sure foundation for the generalised description and providing the means of verifying its correctness or revising it where necessary.

Perhaps there is really more scientific research in geography being undertaken by individuals than I have given credit for, but certainly in geographical periodicals, and in the bibliographies which are published annually, the amount shown is not large; neither is the number of authors as large as might be expected from the importance and interest of the subject and from the activity of those centres where geography is seriously taught. There seems to be no reason why individual research on true scientific lines should not be as active in geography as it is in geology, botany, zoology, or any other branch of knowledge; and, just as in these, the real advance in the subject is dependent on such investigations rather than on travels and explorations in little-known lands, unless these, too, are carried out scientifically and by thoroughly trained observers who know the problems which there await solution, and can read the evidence which lies before them on their route.

If research in these directions is being actively prosecuted, but the appearance of its results is delayed, let us seek out the retarding causes, if there be any, and increase any facilities that may be desirable to assist individual efforts.

Short technical papers of a thoroughly scientific character, such as are the outcome of serious individual research, are, of course, not suitable for those meetings of geographical societies where the majority of the fellows present are not scientific geographers, but should be presented to small meetings of other workers in the same or allied fields, where they can be completely criticised. The reading, discussion, and the publication of papers of this class are for geography a great desideratum, for it is in them and by them that all real advance in the subject is made, rather than by tales of travel, however interesting, if these are not the work of one trained in the subject, having a knowledge of what he should observe, and of what his predecessors have done in the same field. The regional aspect of geography in the hands of its best exponents has given to young geographers a wide and comprehensive outlook on the interaction of the various geographical factors in a region, the responses between the earth's surface and the life upon it, and the control that one factor may exercise upon another. In this form the fascination of geographical study is apparent to everyone, but I sometimes wonder whether the exposition of such a regional study by one who is thoroughly master of the component factors, having a first-hand knowledge of all the material involved, and knowing exactly the trustworthiness of each portion, impresses sufficiently upon the student the necessity of personal research into the details of some problem or phenomenon in such a way as to gain a real working acquaintance with them; or does it, on the other hand, tend to encourage generalisations based on descriptive accounts which have not been verified, and where coincidences and similarities may be accepted without further inquiry as evidence of a causal connection which may not really exist? I imagine that the student may be attracted by the apparent simplicity of a masterly account of the geographical contents and responses involved, and may fail to realise that geographical descriptions, even though technically phrased, are not the equivalent of original quantitative investigation, either for his own education or as a contribution to the subject.

For these reasons I believe that societies can do far more good in the promotion of geography as a science by assisting competent investigators, by the loan of books and instruments, and by giving facilities for the discussion and publication of technical papers, than by undertaking the investigation of problems themselves.

Among the earlier presidential addresses of this section some have laid stress on the importance of the recognition by the State of geography in education; others have represented the great part which the geographical societies have played in supporting and advancing the subject; others again have urged the fuller recognition of geography by educational institutions. I would on this occasion attach especial importance to the prosecution of serious research by individuals in any branch of the subject that is accessible to them, to the discussion of the results of such work by others of like interests, and to the publication of such studies as having a real value in promoting the advancement of scientific geography.